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PRE-DEVELOPMENT PLANNING FOR THE DECOMMISSIONING OF SMALL OPEN-PIT URANIUM DEPOSITS AT THE RABBIT LAKE OPERATION

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L.W. Adrian[1] and J.P. Jarrell

Abstract

It is now generally recognized that rock with sub-economic levels of uranium mineralization has the potential to generate long-term environmental problems which require improved management techniques. The presence of nickel and arsenic in uranium ore deposits can exacerbate the problem.

In planning the development of the Collins Bay A-zone and D-zone ore bodies at Rabbit Lake, Cameco has employed some new methods for developing waste rock management plans, designed to prevent future problems rather than having to react to them after mining has been completed.

The two ore zones were drilled a second time, with the emphasis on the assessment of the quality of the waste rock around the ore. Fifty-seven holes were completed. The core was logged for contaminants, in particular nickel and arsenic, as well as low-grade uranium, which had not been an issue when the ore bodies were initially identified. Chemical analyses were performed for arsenic, nickel, sulphur and uranium in the waste rock halo around the ore bodies. Acid-base accounting, shake-flask tests, and humidity cell and saturated column tests were performed to predict leaching properties of the various constituents under both dry (oxidizing) and flooded conditions. The SERMINE block model was then used to calculate the volumes of each rock type expected to be mined.

The regulatory requirement to model post-decommissioning radioactivity impact gave us the tools which could be used to model the long-term impacts for other non-radioactive elements. Probabilistic assessment of decommissioning alternatives was done by adapting a version of the Uranium Tailings Assessment Program (UTAP). These data, when coupled with experience gained in mining the larger but similar B-zone deposit, enabled us to develop a practical waste rock management plan, balancing costs to segregate waste rock on the basis of its anticipated long-term environmental performance against the future cost to manage an unsegregated waste rock pile. This approach will satisfy environmental concerns while allowing economic development to proceed.

Project Background

Cameco Corporation is currently in the process of developing two relatively small uranium ore deposits at the Rabbit Lake Operation in northern Saskatchewan. As shown in Figures 1 and 2, these deposits are located on the eastern boundary of the Athabaska formation, a geological area with a large number of world-class uranium ore deposits. The A- and D-zone deposits are

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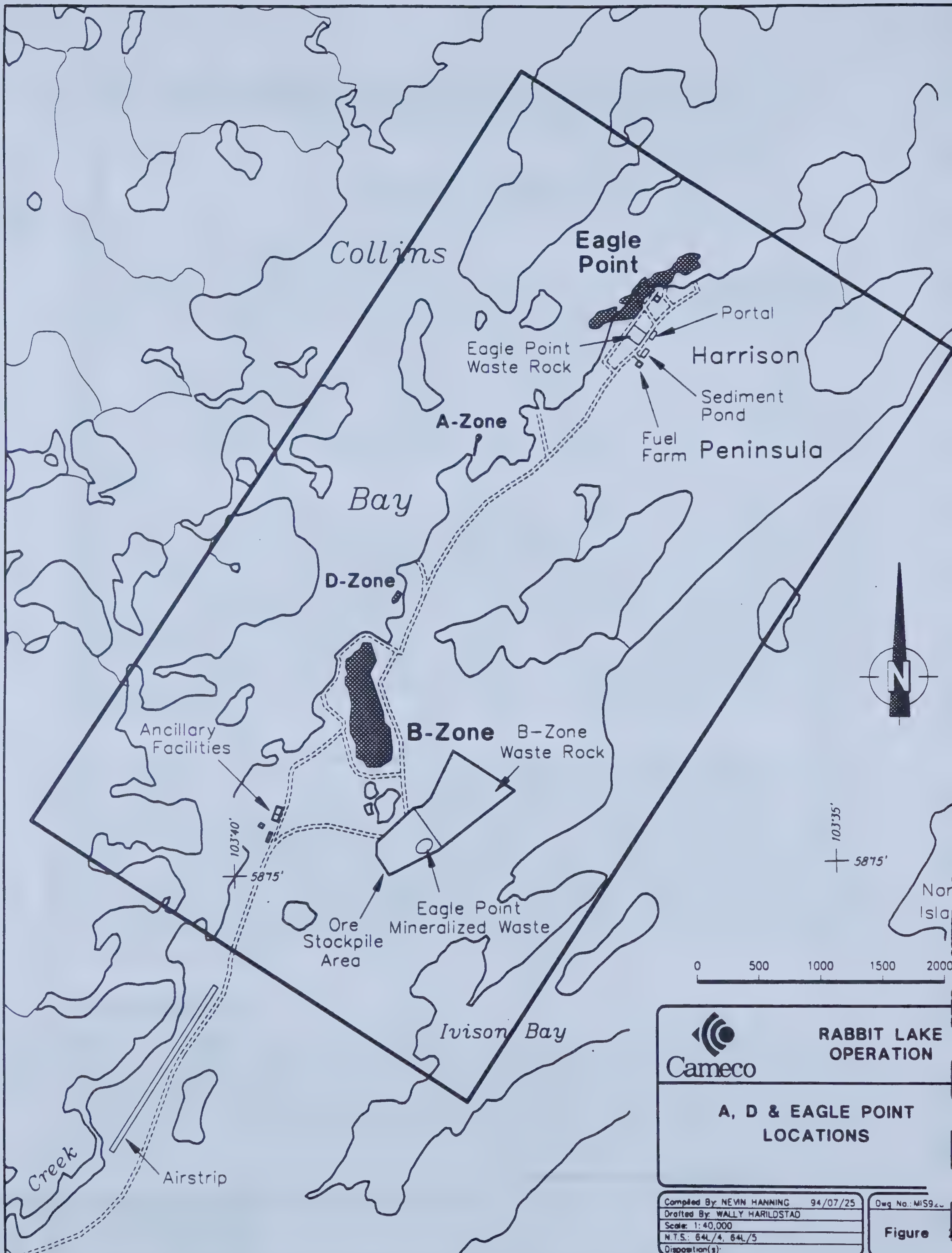
[1]Currently with Cameco's subsidiary Kumtor Operating Company.

N.W.T.
110°00'
60°00'
102°00'
60°00'
URANIUM CITY
FOND DU LAC
STONY RAPIDS
Lake Athabasca
Black Lake
CLUFF LAKE
ATHABASCA BASIN
COLLINS BAY A-ZONE
D-ZONE, EAGLE POINT
Wollaston Lake
RABBIT LAKE
Cree R.
SASKATCHEWAN
ALBERTA
MANITOBA
Reindeer Lake
Cree Lake
KEY LAKE
905
EDGE OF PRECAMBRIAN SHIELD
Foster Lakes
Haultain R.
Mudjatik R.
Foster R.
SOUTHEND
102
BUFFALO NARROWS
Churchill River
155
LA RONGE
Lac La Ronge
FLIN FLON
N
0 50 100 150 km
Cameco
RABBIT LAKE OPERATION
LOCATION MAP
Compiled By: 93/12/20
Drafted By: WALLY HARILDSTAD
Scale: 1:3,200,000
N.T.S.:
Disposition(s):
Dwg No. MIS91023
Figure 1



Collins
Bay
Eagle
Point
Portal
Eagle Point
Waste Rock
Harrison
Sediment
Pond
Fuel
Farm
Peninsula
A-Zone
D-Zone
B-Zone
B-Zone
Waste Rock
Ancillary
Facilities
Ore
Stockpile
Area
Eagle Point
Mineralized Waste
Ivison Bay
Creek
Airstrip
103°40'
58°15'
103°35'
58°15'
N
0
500
1000
1500
2000
Cameco
RABBIT LAKE
OPERATION
A, D & EAGLE POINT
LOCATIONS
Compiled By: NEVIN HANNING 94/07/25
Drafted By: WALLY HARILDSTAD
Scale: 1:40,000
N.T.S.: 64L/4, 64L/5
Disposition(s):
Figure

situated between the former (and much larger) B-zone ore deposit and the currently mined Eagle Point deposit. All of these deposits are situated along the north-west shore of Harrison Peninsula, which defines Collins Bay of Wollaston Lake. The original Rabbit Lake deposit was situated some 10-13 km south of these Harrison Peninsula deposits. The original Rabbit Lake deposit was a land-locked open-pit mine which now serves as the tailings management facility for the Rabbit Lake Operation.

The Harrison Peninsula ore deposit mining methods are defined by the depth of the deposit and proximity to Collins Bay. The B-zone deposit straddled the Bay's shoreline and was mined by altering the shoreline with a steel-cell dyke followed by open-pit excavation. The D-zone deposit, immediately north of the B-zone, extends 90 m offshore, under water depths which range up to 8 m. The A-zone deposit, located 4 km north of B-zone, is situated some 200 m offshore, completely submerged under Collins Bay in water depths that range up to 14 m. The currently mined Eagle Point deposit is located 4.8 km north of B-zone. It straddles the shoreline, but because of the depth of the ore, is being mined by underground methods.

Both the A- and D-zone deposits will be mined in a fashion similar to that used for B-zone, namely shoreline alteration with steel-cell dykes followed by open-pit excavation. The similarity to B-zone is not just in the mining method. From an environmental perspective, the nickel and arsenic contents of the A-, D-, and B-zone deposits make them different from the essentially nickel- and arsenic-free Eagle Point and Rabbit Lake deposits.

Both A-zone and D-zone deposits are characterized by uranium mineralization in clay-altered lenses hosted in sandstone formations. The sandstone is underlain and bordered by basement gneisses and paragneisses rock and covered by overburden sandy tills. Concerns with variable nickel, arsenic, and sulphur contents in waste rock and tills surrounding the deposits, and the degree to which they are associated with uranium were the fundamental technical questions addressed in pre-development environmental planning. These factors, along with the inevitable comparison with current B-zone environmental performance largely shaped waste rock management and decommissioning plans.

Key comparative parameters between the three Harrison Peninsula open-pit developments are as follows:

Location	Ore Grade (% U_3O_8)	Ore Volume (m^3)	Waste Volume (m^3)	Impoundment Dimensions	
				Size (ha)	Water Volume * (10^6 m^3)
B-Zone	0.7%	1,000,000	5,600,000	28	5.2
A-Zone	5.7%	54,000	340,000	10.5	0.8
D-Zone	2.2%	46,000	500,000	6.5	0.6

* Based on proposed decommissioning plan.

At B-zone, the open pit was flooded shortly after completion of an eight year (1984-1991) mining phase. Prior to flooding, approximately 430,000 m^3 of waste rock and 100,000 m^3 of special waste were placed in the bottom of the pit. The special waste (sub-economic uranium mineralization) was covered with 2 m of till prior to flooding. Mineralized zones on the pit walls were left exposed and the dyke was left intact. Within the flooded pit, arsenic and nickel concentrations are the only two parameters which are currently above Saskatchewan Surface Water Quality Objectives (SSWQO) for protection of the quality of aquatic habitat. The arsenic and nickel are primarily soluble. Radionuclide and total suspended solids concentrations are very low. The flooded pit has no measurable impact on Collins Bay, by virtue of the dyke and relatively low contaminant concentrations. Current decommissioning issues associated with the former B-zone development can be summarized as follows:

- Current model predictions indicate that, if the pit is left as is, arsenic and nickel could take up to 200 years to reach SSWQO from their current levels (both at about 0.3 mg/L). Recovery rate is primarily governed by contaminant leaching from oxidized pit wall mineralization and contaminant removal by phytoplankton. Methods to accelerate or augment the natural recovery process are under active investigation.

- The long-term stability of water levels within the flooded pit is currently an open question. If water levels continue to rise, water handling procedures may become a primary "driver" in the decommissioning plan.

- The relatively large waste rock pile generated from the mine development is about 50% overburden and 50% waste rock. Although this pile can generally be characterized as a non-mineralized, non-acid generating source, localized seeps from the toe of the pile exhibit low pH and arsenic/nickel concentrations well above applicable SSWQO. Mechanisms which generate these seeps include localized pockets of acid-generating basement rock, impact of first-flush oxidized residual mineralization and thawing of initially trapped pore water. In the post-operational decommissioning phase, water collection and treatment facilities will no longer be available. The assimilative capacity of surrounding wetlands and effectiveness of till covers are being investigated.

Decommissioning Plan Development Work

Against the backdrop described above, it was decided to drill both A- and D-zone deposits a second time. During the winter of 1993/94, 57 holes were drilled. Locations were chosen to minimize entry into the ore body and maximize entry into the mineralized halo and waste rock surrounding the ore bodies. Samples were categorized as overburden, sandstone and basement rock. In total, the following analyses were done:

Test	Number
• Comprehensive Solids Analysis	521
• Acid-Base Accounting	39
• Short-Term Static Leach Extractions (Shake-flask tests)	26
• 20-Week Kinetic Leach Extractions (Column Tests)	
- Unsaturated	12
- Flooded	6

Drill hole log data and chemical analysis data were coupled with data from the original exploration phase definition drilling conducted prior to 1985. Assays from exploratory drilling had predictably focused on uranium and nickel analysis, with very little information available for arsenic and no data available on total sulphur. All available data were fed into a finite-element geological and statistical program (SERMINE, developed by Cogema). The model calculated average metal content for 7.5 m × 7.5 m × 3 m blocks by kriging drill hole analytical results (interpolation technique). Based on past experience, care was taken to exclude the ore body when calculating metal grades in the waste rock halo. Results were compared with the following waste classification criteria:

Parameter	Clean Waste Rock (%)	Environmental Special Waste (ESW) (%)
Arsenic	≤0.02	>0.02
Nickel	≤0.02	>0.02
Sulphur	≤0.20	>0.20
Uranium Oxide	<0.03	≥0.03 to ≤0.14

From this modelling, it was determined that in both A-zone and D-zone pits, the majority of the material to be removed is overburden, with basement rock removed in the easterly (shore) side of the pit and sandstone on the westerly side, in conformance with the general behaviour of the Collins Bay fault which runs through these deposits.

In summary, the following estimates were made from block modelling, assuming an ability to correctly classify each block:

Waste Rock Type	A-Zone (% of total mass)	D-Zone (% of total mass)
Overburden		
Clean ESW	64.3 4.1	87.3 1.4
Sandstone		
Clean ESW	8.3 5.2	4.6 2.1
Basement Rock		
Clean ESW	- 18.1	3.9 0.7
Overall Totals		
Total Clean	72.6	95.8
Total ESW	27.4	4.2
Total (excluding ore)	100%	100%

When coupled with results from leach extraction tests, the following overall conclusions were derived:

For overburden: Metal concentrations are low, and the material is not acid generating. Use of a conventional radiometric scanner to segregate on uranium content will effectively control arsenic and nickel contents as they are closely correlated. The material is suitable for either subaerial or subaqueous management.

For sandstone: Segregation on uranium content will effectively control arsenic, nickel, and sulphur contents, but not completely. Without chemical assay, pockets of contaminated waste rock are possible, particularly at lower elevations. Leachate quality is improved under subaqueous conditions relative to subaerial conditions.

For basement rock: Metal concentrations are generally higher than in sandstone. Segregation solely on uranium content will not control nickel content sufficiently well and the rock is potentially acid generating. All basement rock should be considered Environmental Special Waste and would behave better if disposed of under water. Metal grades in D-zone basement rock are generally lower than in A-zone basement rock, although kinetic tests still generate elevated leachate nickel levels.

The most important conclusion from this work is that while some overburden from both A-zone and D-zone contains over 0.03% U_3O_8, which can be segregated by radiometric scanning, overburden with less than 0.03% U_3O_8 contains low-metal values, is non-acid generating and could be used for cover material.

The ratio of pit volume to water volume, and the minimal bulking factor associated with overburden tills have a major impact on what is and what is not practical, in terms of pit decommissioning. It is clearly not feasible to fill both open pits to the height of the dyke walls without importation of large volumes of clean material.

The level of correlation between arsenic, nickel, sulphur and uranium levels in the majority of the waste make the proposed waste rock classification criteria workable without resorting to detailed chemical assay to provide the necessary controls on waste rock segregation. Use of conventional mining radiometric scanners and horizon elevation control can provide the necessary segregation.

Developed Reclamation and Decommissioning Plan

As might be expected, there is a wide variety of decommissioning alternatives available for the A-zone and D-zone developments. There is also the option of integration with B-zone plans.

In all, nine scenarios were considered. A version of the Uranium Tailings Assessment Program (UTAP) was used to evaluate all scenarios. This model includes both source term estimation and environmental transport models, structured to predict impact on defined receptor groups. Non-radiological parameters can be evaluated by concentration or receptor uptake. Radiological parameters can be evaluated by receptor committed dose. A number of variables (such as initial contaminant concentrations and maximum source term leachate mass estimates) are input as probability distributions in order to predict impact range at any given time and place.

Various assumptions regarding the effectiveness of waste rock/environmental special waste (ESW) segregation were made in this modelling, ranging from chemical assay of each mined block to a combination of radiometric scanning and horizon elevation control to achieve compliance with the proposed waste rock classification criteria. Modelled scenarios also considered a variety of disposal options for clean waste rock and ESW, with clean overburden materials disposed of beside completed pits, moved back into the completed pits, or moved to the B-zone waste rock pile to help improve precipitation seepage control. In all scenarios, ESW materials were relocated back into their original pit, or consolidated into the D-zone pit. The D-zone pit, although larger than the A-zone pit, would require less fill if one wished to avoid ponded water behind a dyke, given the smaller size of the overall impoundment. Even in this consolidation scenario, ponded water cannot be avoided unless one uses the bulk of mined clean overburden as pit fill. One model run considered the long-term impact of breaching all three dykes.

Overall conclusions were as follows:

- Permeability control on the B-zone waste rock pile has little effect on the water quality in the B-zone pit. This is because peak concentrations in the pit are related to initial flooding/solubilization of oxidized wall rock and not the result of loadings from the contaminant front slowly migrating from the waste rock pile much further in the future.

- Within the flooded A-zone pit, peak concentrations for all modelled parameters are expected to remain below SSWQO except for nickel. Without intervention, it would take about 10-20 years to reach SSWQO in a closed A-zone pit. Peak concentrations for all parameters occur immediately after flooding.

- Within the flooded D-zone pit, which generally has greater water cover and reduced ESW quantities compared to A-zone, peak concentrations for all modelled parameters are expected to remain below SSWQO.

- The relatively elevated metal concentrations seen in the B-zone pit are not expected to be repeated in either the A-zone or D-zone flooded pits due to the mining methods used. While the B-zone pit walls were exposed to oxidizing conditions for almost eight years, the A-zone and D-zone pits will be mined during one winter each.

- As expected, dyke breaching significantly shortens the time necessary to meet SSWQO within the former impoundments. With limited breaching and minimal efforts to promote water exchange with Collins Bay, times to meet SSWQO are generally in the range of one half of those predicted for a closed pit.

- Regardless of the decommissioning scenario chosen, there will be a non-measurable effect on water quality in Collins Bay or Wollaston Lake.

- Receptor dose assessment shows that total dose attributable to A-zone, B-zone and D-zone decommissioning is a very small fraction of natural background radiation.

In selecting decommissioning options for the two new open-pit developments, Cameco took a conservative approach on clean vs. contaminated waste segregation. In both cases, elevations have been established above which there is reasonable confidence that grade control and conventional radiometric scanning will generate a clean overburden till pile. This clean material will be stockpiled beside the open pit, to temporarily serve as a pad for the material below the cut-off elevation. All material below the cut-off elevation will be classified as ESW and will be relocated back into the pit and covered with clean till prior to mine flooding. The volume of expected clean material included as ESW by simple grade control does not justify the cost to segregate it out by chemical analysis:

Category	A-Zone	D-Zone
Estimated Actual ESW Volume Below Cut-Off Elevation	102,000 m^3	23,000 m^3
Estimated Clean Waste Volume Below Cut-Off Elevation	92,000 m^3	57,000 m^3
Total Waste to be Relocated to Pit	194,000 m^3	80,000 m^3
Additional Till Cap Volume Placed Prior to Flooding	102,000 m^3	55,000 m^3
Till Material Retained For Other Reclamation Purposes	45,000 m^3	368,000 m^3

Prior to flooding, upper benches of the pit at the water surface contact point will be sloped and rip-rapped with clean waste rock to prevent shoreline erosion and associated TSS loadings to the water column. When water quality has reached levels acceptable to the regulatory agencies, Cameco will seek approvals to breach the dyke at the abutments to allow free exchange of surface waters. Accelerated mining over winter months should minimize contamination of the clean till used to temporarily store the ESW beside the pit.

Since all A-zone and D-zone sandstone and basement rock is being treated as ESW, the need for field verification is reduced to testing the clean overburden till piles. Daily and weekly composite samples will be taken to verify performance against the criteria. If failure is indicated, the material will be treated as ESW. In practical terms, this means either immediate removal of the ESW overburden material if the problem is extensive, future segregation when the till pile is relocated for other purposes, or consideration of a low permeability engineered cover in the unlikely event that the till pile is left in place.

Development of these two ore bodies also involves compensation for the loss of fish habitat resulting from the construction of the two impoundment dykes. Following a thorough fish spawning and habitat investigation of Collins Bay in 1994, Habitat Compensation Agreements were reached with Provincial and Federal regulatory agencies. The two agreements call for construction of 5,500 m^2 of lake whitefish spawning shoals and 10,250 m^2 of shallower marsh habitat.

Current Project Status

The regulatory approval process leading up to production mining has been arduous when one considers that the first regulatory submission which included A- and D-zone developments was filed in May, 1986. Final production approval was issued by the Atomic Energy Control Board (AECB) on September 21, 1995 and by Saskatchewan Environment and Resource Management (SERM) on September 25, 1995. At D-zone, overburden stripping is under way, in anticipation of production mining over the 1995/96 winter. This will be followed by waste backfilling in the spring of 1996 and reflooding in the summer of 1996. At A-zone, construction work has commenced on the dyke structure. Mining is scheduled for the winter of 1996/97, following a time line similar to D-zone development. SERM has approved the proposed decommissioning plan summarized in this paper. AECB on the other hand, has requested some additional modelling work prior to endorsement of the plan. At a minimum, the work completed to date has demonstrated that waste rock and decommissioning issues can be mitigated.

Reclamation and Decommissioning Issues

In developing the reclamation and decommissioning plan for A- and D-zone developments, we have attempted to develop a plan which addresses the environmental "drivers" which define the performance of the former, and much larger, B-zone development. Segregation of waste rock to clean and potentially problematic categories provides more decommissioning alternatives. Minimizing the time in which residual mineralization in pit walls is allowed to oxidize by using a compressed mining schedule centred around winter months to slow oxidation rates should reduce contaminant leaching into the flooded pit. Subaqueous disposal of problematic waste rock under a till cap should reduce leachate generation rates and problems with surface disposal of residual waste stockpiles. Preservation of clean stockpiles of overburden tills and lake bottom organics make economic and environmental sense. These stockpiles are a valuable commodity in other decommissioning work to be undertaken at the Rabbit Lake site. The selected waste segregation technique is compatible with a compressed mining schedule and represents a balance between segregation costs and efficiency.

The concept of creating an artificially impounded body of water with eventual hydraulic connection to Collins Bay produces mixed opinions amongst those who rule on decommissioning proposals for these open-pit mines. In our view, the issue reduces to the credibility of the modelling predictions. These predictions, based on current understandings of the mechanisms which govern the concentrations of nickel and arsenic in flooded pit water, forecast that the steps proposed should generate flooded pit water qualities which are about one order of magnitude better than those seen in the B-zone pit. If we were to completely backfill the A- and D-zone pits, we would obviously eliminate any possibility of short-term development of an isolated body of water which would be above SSWQO established for the protection of aquatic habitat. However, in terms of loading to the environment, this solution would produce limited, if any, benefit at a relatively high cost.

If the modelling predictions prove accurate, then the water quality in the flooded pits should lead to a straightforward approval process to breach the dykes and allow free exchange of surface waters, within a reasonable time frame. If the modelling predictions prove wrong, or if the approval process becomes untenable, then some form of contingency would need to be implemented. Four possible alternatives could be considered:

- Accelerate the natural recovery process as being investigated for the flooded B-zone pit,
- Implement some form of pump-and-treat system to accelerate recovery from the "first flush" mechanism,
- Undertake some interim controlled release phase prior to undertaking the work to remove all or part of the dyke, thereby demonstrating control of any environmental impact from the work, or
- Drain the flooded pits and fill them with clean waste material.

In any event, we believe that we have demonstrated that these two mine developments can proceed in an environmentally-responsible fashion.

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